weighted fast spin-echo (3000/80) (T2WI), T2*_T2-weighted gradient echo (4000/80) (T2*2D), T2*_3-dimensional T2-weighted gradient echo [TR/TE1/deltaTE](37/14/7.3) (T2*3D), and contrast-enhanced T1-weighted spin-echo (607/12) (CE-T1WI) in all cases. Contrast-enhanced T1-weighted MRI was performed with gadopentetate dimeglumine. The quality comparison of the five sequences (T1WI, T2WI, T2*2D, T2*3D and CE-T1WI) was conducted by a single radiation oncologist and two radiation technologists. These observers subjectively scored all of the images based on the five following evaluation items: the definition of outline of the prostate; apex vs. soft tissue; base vs. bladder; base vs. seminal vesicle; and gold fiducial marker detection. A score from 1 to 3 (1 [poor], 2 [moderate], 3 [good]) was assigned to each of the items accordingly. Higher score was regarded as denoting better visualization. We compared the mean scores for each item.

Results:

Table
The mean imaging score of the magnetic resonance imaging (MRI) pulse sequences to define the gold fiducial marker

	Outline of prostate	Apex vs. soft tissue	Base vs. Bladder	Base vs. SV	Fiducial marker definition
Observer 1					
T1WI	1.8	1	1.2	1.2	1
T2WI	2.7 †	2.3 †	2	2 †	1
T2*2D	2	1	1.3	1	1.1
T2*3D	1.7	1.2	1.1	1.1	2 †
CE-T1WI	1.6	1.4	1.6	1.1	1
Observer 2					
T1WI	2	1.6	1	1.2	1
T2WI	2.5	2.3 †	2.4	2.3 †	1
T2*2D	2	1.3	1.3	1	2 ‡
T2*3D	1.8	1.4	1.1	1	2.3 ‡
CE-T1WI	2	1.7	1.9	1.6	1.3
Observer 3					
T1WI	1.8	1.2	1.6	1.2	1
T2WI	2.2	2	2	2	1.2
T2*2D	2	2.1	1.4	1.7	2.4 ‡
T2*3D	2.1	1.7	1.8	1.8 †	2.3 ‡
CE-T1WI	1.6	1.9	1.6	1.4	1.5

Abbreviations: SV, seminal vesicle.
One radiation oncologist and two radiation technologists subjectively scored the images based on 5 evaluation items. Scores of 1 to 3 (1 [poor], 2 [moderate], 3 [good]) were assigned to all items. Higher scores denoted the superior definition of the prostate edge and gold fiducial markers.
† The significantly highest score among five sequences ($p < 0.01$).
‡ A significantly higher score than that in three other sequences ($p < 0.01$).

Our data are shown in the Table. T2WI was significantly superior to the other sequences in terms of the definition of the prostate. T2*3D was significantly superior to the other sequences in terms of the definition of the fiducial marker.

Conclusion: The most important purpose of the study was to accurately identify the marker. T2*3D was the best sequence for achieving this objective. The superiority of T2*3D in defining the marker meant that although T2W1 provided the highest level of precision in the outline of the prostate, T2*3D provided a better balance between the contouring of the prostate and defining the marker.

EP-1831

Inter-physician variability in delineation of clinical target volume of uterine cervical carcinoma

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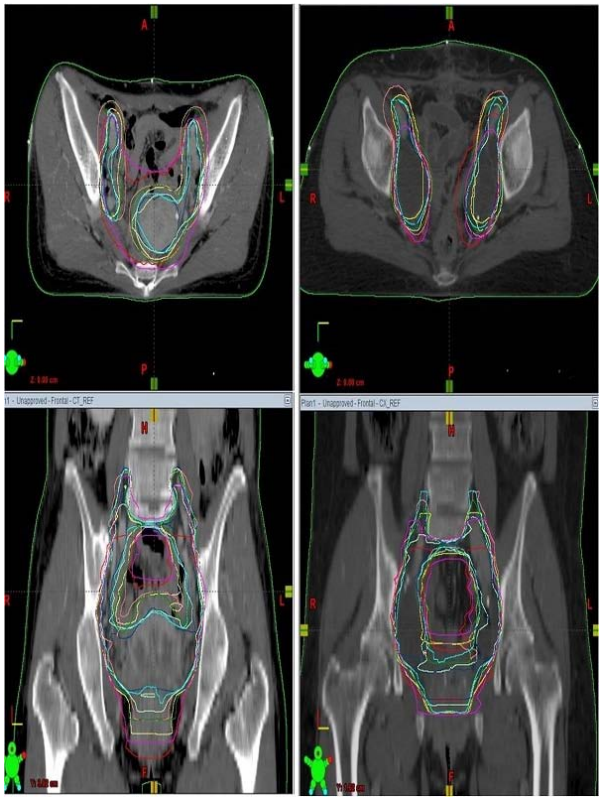
Purpose or Objective: As intensity modulated radiation therapy (IMRT) is becoming a standard option for cervical cancer radiation therapy (RT), one of the major uncertainty components is the definition of the clinical target volume (CTV). Despite several guidelines, wide discrepancy can still exist. The aim of this study is to determine inter-observer variability in delineating CTV for definitive and postoperative RT for cervical cancer.

Material and Methods: Eight radiation oncologists from different centers whose subspecialty are gynecologic cancer contoured CTV on the planning computed tomography (CT) scan of two patients, each of definitive and postoperative RT case (Fig. 1).



For volumetric analysis, we compared delineated volumes in terms of the individual/median volume ratio, generalized conformity index (CIgen). For spatial difference information, center of mass (COM) was used. IMRT plan was made based on one of the collected CTVs, and dose coverage was compared.

Results: The CTV volume for definitive case was 213-918 ml, with individual/median volume ratio of 0.51-1.41. The CIgen was 0.53. The mean values of the three-dimensional distances of the average COM to each COM were 7.8 mm. The largest difference was seen in superior-inferior direction, depending on common iliac lymph node region coverage and the length of inclusion of vagina. On dose coverage analysis, 95% of prescription dose covered 80.3% (range, 62.2 – 96.0%) of planning target volumes (PTV) generated by 8 physicians. Parametrial and paravaginal areas were most frequently underdosed. The CTV volume for postoperative RT case was 266-562 ml, with individual/median volume ratio of 0.65-1.38. The CIgen was 0.563. The mean values of the three-dimensional distances of the average COM to each COM were 5.3 mm in postoperative case. Ninety-five percent of prescription dose covered 80.9% (range, 66.4 – 94.8%) of planning target volumes (PTV) from 8 hospitals. Presacral, tumor bed and paravaginal areas were most frequently underdosed.

Conclusion: A large inter-physician variability in CTV delineation concerning the magnitude and relative location of volumes was observed. Continuing education of proposed

guidelines on CTV definition and knowledge of commonly missed/disconcordant CTV areas cannot be overemphasized to avoid such difference.

EP-1832

Improved 4DCT quality using true phase based triggers

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Purpose or Objective: For Toshiba Aquilion LB CT scanners, the reconstruction quality of 4DCTs is strongly dependent on the accuracy of cycle based online trigger pulses. Two consecutive triggers are used to define a breathing cycle which is divided into respiratory phases of equal duration. As a consequence, any deviation in the length of the inspiration or expiration period in relation to the whole breathing cycle will result in image artifacts and a higher probability of misinterpretations. The aim of this work is to improve 4DCT quality by using amplitude based triggers for each individual breathing cycle.

Material and Methods: The trigger signals for the 4DCT reconstruction are originally provided by the Sentinel™ optical surface scanner (C-RAD AB, Sweden) using a threshold method in order to generate online trigger pulses. These always have to occur before the actual maximum of the curve and are used to reconstruct the 4DCT phases based on an equally divided breathing cycle (0% - 90% in 10% steps) for phase-based reconstruction. A second 4DCT is reconstructed using the true inhalation peak triggers created by an offline tool, also with phases of equal time for each cycle. Furthermore, a single trigger for each breathing phase is sent to the CT for a third reconstruction of all motion states based on the amplitude (e.g. 10%, 20%, etc.) of the breathing curve in relation to the maximum and minimum of one cycle. The absolute volume of a tumor inside of a moving chest phantom, which serves as a direct measure for reconstruction quality, has been determined for each motion state of the reconstructed 4DCT for 10 different curves (2 sinusoidal, 8 patient breathing curves),

Results: Reconstructing the 4DCT solely according to the online trigger pulses proposed by Sentinel™can lead to a mean deviation in the volume of the tumor of up to 2,98% ± 4,65% compared to the CT reconstruction of the same tumor without any movement. When selecting the optimal trigger point at maximum inhalation offline and dividing the breathing curve into phases of equal duration, the error in volume is reduced to 0,19% ± 2,84%. Generating an amplitude based set of trigger pulses for each individual breathing cycle, the error in volume has been observed with 0,25% ± 0,29%.

Conclusion: Although the method of reconstructing 4DCTs using the amplitude-based information for each breathing cycle provides the best representation of the tumor volume, it appears to be quite impractically as every trigger file for each phase has to be sent into the CT for a single reconstruction of this motion state. This will be hard to accomplish in a clinical workflow and is prone to errors. A reconstruction of the 4DCTs based on equally divided respiration phases over time with the trigger points set to the true maximum of the breathing curve serves as a valid compromise, with minimal extra workload clinically and improved 4DCT image quality.

EP-1833

Improved proton stopping power ratio estimation for a deformable 3D dosimeter using Dual Energy CT

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Purpose or Objective: The highly localized dose distribution in proton therapy (PT) makes this treatment modality sensitive to organ motion and deformations. E.g. in proton pencil beam scanning interplay effects may be significant, resulting in dose degradations. Due to the complexity of PT dose delivery, investigations of the consequences of motion and of motion mitigation strategies may benefit from the use of 3D dosimetry. A new family of silicone-based 3D dosimeters is currently being developed. These dosimeters can be moulded into anthropomorphic shapes and can be deformed during beam delivery, which allows for simulation of organ motion and deformation.
Treatment planning with protons is based on CT scans of the patient anatomy and a conversion of the HU for the tissue to a stopping power ratio (SPR) relative to water. To ensure that the same procedure can be performed for the dosimeter it must be verified that its SPR is estimated correctly from its HU. The aim of this study was therefore to investigate if the use of Dual Energy (DE) CT and dedicated DE calibrations can improve the calculation of the SPR for the dosimeter compared to use of Single Energy (SE) CT together with the stoichiometric calibration method.

Material and Methods: A thin slab of the dosimeter material was placed in a water tank and irradiated with a 60 MeV proton beam. The range of the protons was measured with and without the dosimeter intersecting the beam to determine the range difference. The SPR of the dosimeter was calculated from its thickness and the range difference.
The dosimeter was subsequently CT scanned with a Dual Source CT scanner (Siemens Somaton Definition Flash). First a CT scan was obtained in SE mode with a tube voltage of 120 kVp, and this scan was used in the stoichiometric calibration. Next a set of CT scans was obtained in DE mode with a tube voltage pair of 80/140Sn kVp (Sn: 0.4 mm extra tin filtration); this CT image set was used for SPR calculation with two published DE calibrations. The CTDIvol of the two scanning modes was set to be the same (~20 mGy).

Results: From the range measurements, the SPR of the dosimeter was calculated to be SPRmeas = 0.97. The two DE calibration methods both gave an estimate of SPRest = 1.01, whereas the SE stoichiometric calibration estimate was SPRest = 1.10. The measured SPR did not fall on the stoichiometric calibration curve of the reference tissues (Figure; the high content of silicon makes the dosimeter not tissue equivalent). The dosimeter was found to have a HU corresponding to bone (CT number = 135 HU) but a SPR corresponding to fat.